Rivers Inlet Echo Sounding Program 1967-1988

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ABSTRACT

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Rivers Inlet supports the largest returning sockeye salmon stock within the Central Coast (Department of Fisheries and Oceans Statistical Areas 6-10). An echo sounding program has been conducted since 1967 to provide managers with an early indication of the stock abundance and to assist in the in-season management of the commercial gillnet fishery. This report details the methods used to interpret the Rivers Inlet echo sounding data over the period 1967-1988. An historical record of the sounding equipment used and the estimated daily sockeye abundances is presented in accompanying appendices.

RESUME

Goruk, R .D. and B.L. Thomson. 1988. Rivers Inlet echo sounding program 1967-1988. Can. Man. Rep. Fish. Aquat. Sci. 1989. iii + 27 p. + Appendices

L'inlet Rivers reçoit le plus important stock de saumon rouge qui revient frayer dans la zone centrale de la côte (zones statistiques 6-10 du ministère des Pêches et des Océans). Depuis 1967, un programme d'écho-sondage a été mis sur pied afin de fournir aux gestionnaires des indications précoces sur l'abondance du stock et pour permettre l'exploitation pendant la saison de la pêche commerciale aux filets maillants. Le présent rapport décrit en détail les méthodes utilisées pour interpréter les données d'écho-sondage provenant de l'inlet Rivers pour la période de 1967 à 1988. On trouvera dans les annexes jointes des données historiques sur les appareils d'écho-sondage et l'abondance quotidienne estimée des saumons rouges.

INTRODUCTION

Rivers Inlet, located in the southern area of the Central Coast (Fig. 1) has the largest returning sockeye salmon (Oncorhynchus nerka) stock within the Central Coast. The majority of the sockeye producing streams of this area flow into Owikeno Lake, which is drained by the Wannock River into Rivers Inlet.

During the period approaching the mid 1960's numerous improvements to commercial fishing gear increased the efficiency of gillnets. In 1965 and 1966, it became apparent that early catch statistics could no longer be used to estimate total stock abundance (Wood and Mason 1971).

In 1967, a preliminary study was initiated by F.E.A. Wood to develop a better estimate of stock size. The study ran from 1967 to 1970 to determine the feasibility of estimating stock abundance using hydroacoustic techniques. Rivers Inlet sockeye salmon hold and increase in numbers at the head or easternmost portion of the inlet after passing through the commercial fishery occurring in the outer areas. Results from the study indicated that stock size in Rivers Inlet could be determined by hydroacoustic enumeration (Wood and Mason 1971).

Early sampling indicated that sockeye salmon adults represent approximately 95% of the fish in the Rivers Inlet area during the month of July. The 1967-1970 echo sounding program identified characteristics of the sockeye salmon stocks in the Rivers Inlet area that have helped in determining the most appropriate sampling procedure to follow. The study showed (Wood and Mason 1971):

1) during daylight conditions the sockeye tend to orient themselves in fairly deep, dense schools in which individual targets cannot be identified on the echogram. However, as darkness approaches these schools ascend and spread, allowing individual salmon targets to be distinguished by the echo sounder. Sounding during these dark conditions has continued throughout the history of the Rivers Inlet sounding program.
2) within the inlet the adult salmon occupy the saltwater layers and tend to avoid the surface freshwater layer.
3) during rising tides, the fresh/saltwater interface layer remains relatively thick.
4) the salmon may continue to move into the area for several weeks after upstream migration has begun. Because of this, there is no one time when all the migrating salmon are within the area monitored.
5) Generally, 95-99% of the counts are found in the top 10 fathoms.

From 1967 until the present, the Rivers Inlet echo sounding program has been used as an effective aid to managers in providing early indication of the stock abundance and to assist in the inseason planning for the commercial sockeye fishery.

ECHO SOUNDING THEORY

Hydroacoustic sampling methods have been used to monitor fish populations for 50 years (Thorne 1983). A vertically oriented sonar system, termed an echo sounder, is usually used. The echo sounder emits a pulse of sound energy that is reflected back to the sound source on hitting targets such as fish or the sea bottom. The returning 'echo' is registered by the echo sounder and is displayed on either an oscilloscope or paper recorder.

A transducer connected to the echo sounder emits a sonar beam. The sound intensity of the beam is greatest along an axis perpendicular to the transducer surface. The sound is reflected back to the transducer as an echo. The nature of the echo received by the transducer is a function of the target type, the instrument characteristics and the operating conditions. Water temperature, salinity and depth affect the speed of sound in water. The target strength of an object is affected by its size, reflective characteristics and orientation in the sonar beam. As an example, fish with swimbladders have a target strength 10 dB greater than a fish of similar size without a swimbladder. The swimbladder is estimated to be responsible for 90% of the returning echo (Thorne 1983).

The shape of the echo is a function of the paper speed, the vessel speed and the difference between the horizontal and vertical scales as represented by the recording device. Single fish echoes (or traces) are characteristically an inverted v-shape. This is caused by the changing distance between the fish and the transducer as the fish moves through the sonar beam (Forbes and Nakken 1972). Conversion factors are applied to the total number of traces recorded to obtain an estimate of the number of fish in the area surveyed.

METHODS

GRID AREAS

Over the years, three survey areas have been established at the head of Rivers Inlet (Fig. 2). Echo sounding has been conducted within these areas or grids along fixed transects. Location of the transects is based on obvious land formations and patterns that can easily be located in both day and night surveys. These transect patterns allow the grid area to be repeatedly surveyed by the sounding vessel in a consistent manner. Comparisons can then be made on subsequent echosounding periods.

The three grid areas are the Miss Robyn, the R.D. 102 and the Thrasher or Thrasher Rock grid. The Thrasher grid was used occasionally in the 1970's to give an indication of the number of sockeye moving into the sanctuary area. In recent years, only the Miss Robyn and R.D. 102 grids have been used to give an estimate of sockeye stock strength.

During the first part of July, sockeye tend to build in numbers within the R.D. 102 grid. Migration into the Miss Robyn grid begins as new fish continue to move into the R.D. 102 grid. Sockeye numbers build in both grids. As the third week of July approaches, heavier concentrations of fish build up in the inner regions of the Miss Robyn grid. Shortly after this period, they begin migrating up the Wannock River into Owikeno Lake. Once migration has occurred stock estimation becomes unreliable because the number of salmon entering and leaving the sounding area cannot be determined. Salmon hold in the lake until the beginning of September and then move into the streams to spawn. Spawning will continue until the beginning of November. It is unknown what initiates upstream migration, though it is probably linked to tide levels, river levels and/or the fish density in the innermost areas of the Miss Robyn grid.

Transect patterns have changed only slightly from 1967 to 1988 in the Miss Robyn and R.D. 102 grids (Fig. 3 to 6). Figure 7 illustrates the transect pattern followed by the vessel Thrasher Rock in 1969 using a 106 kHz Ross straight line sounder. Figure 8 outlines the outer Thrasher grid.

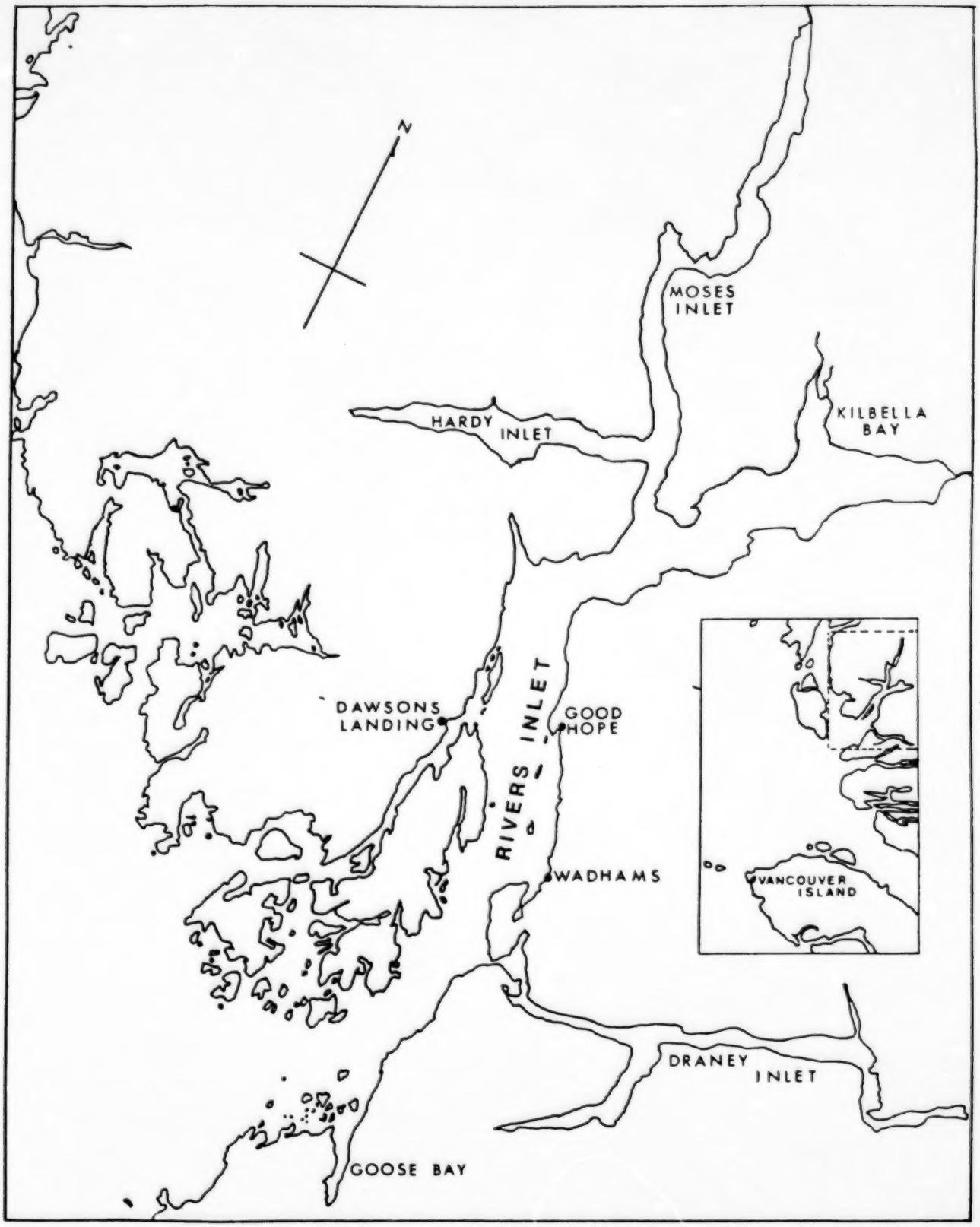

FIG. 1 LOCATION OF RIVERS INLET, B.C.

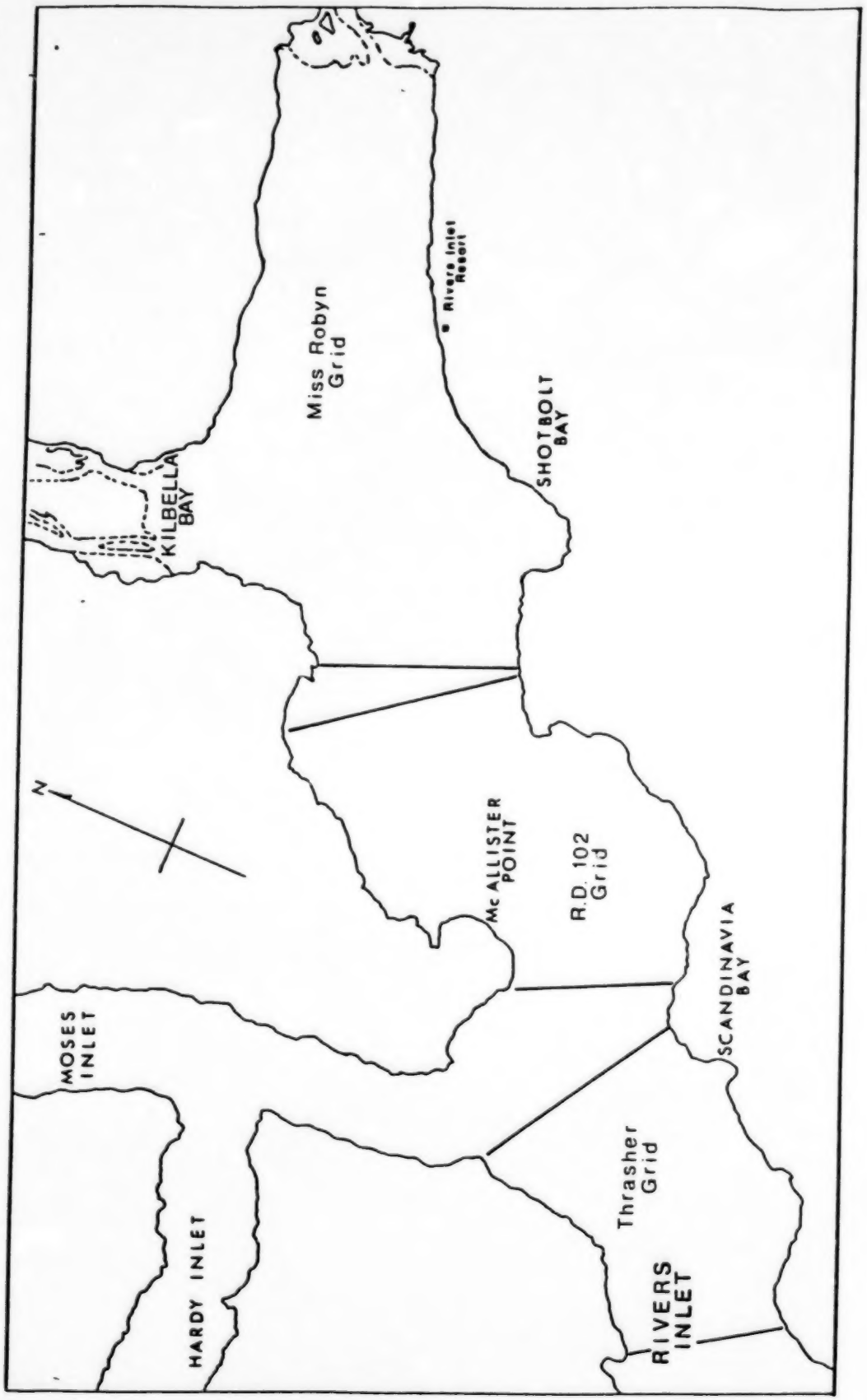

FIG. 2 POSITION OF GRID AREAS IN RIVERS INLET

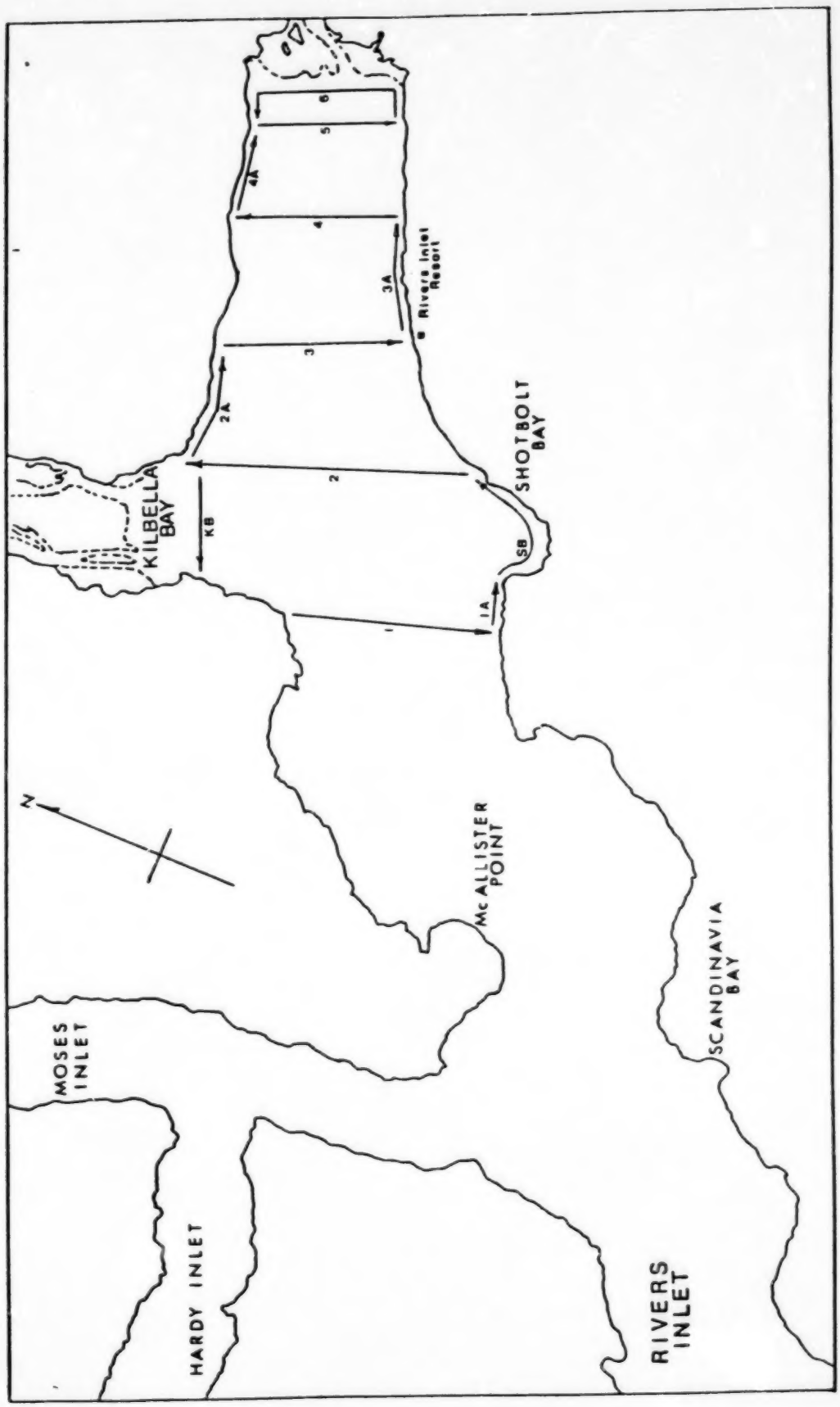

FIG. 3 MISS ROBYN GRID 1967-1970

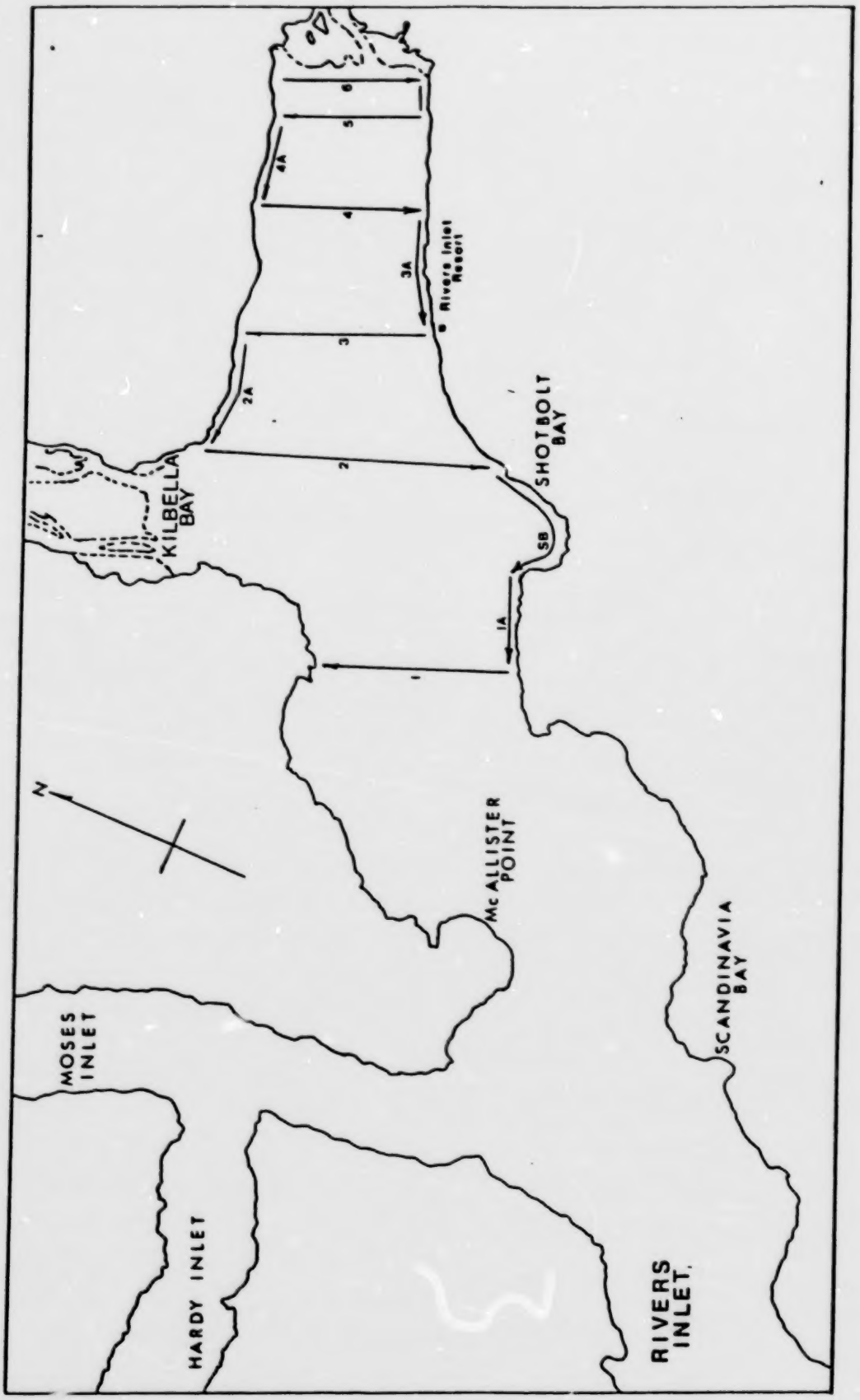

FIG. 4 MISS ROBYN GRID 1971-1983

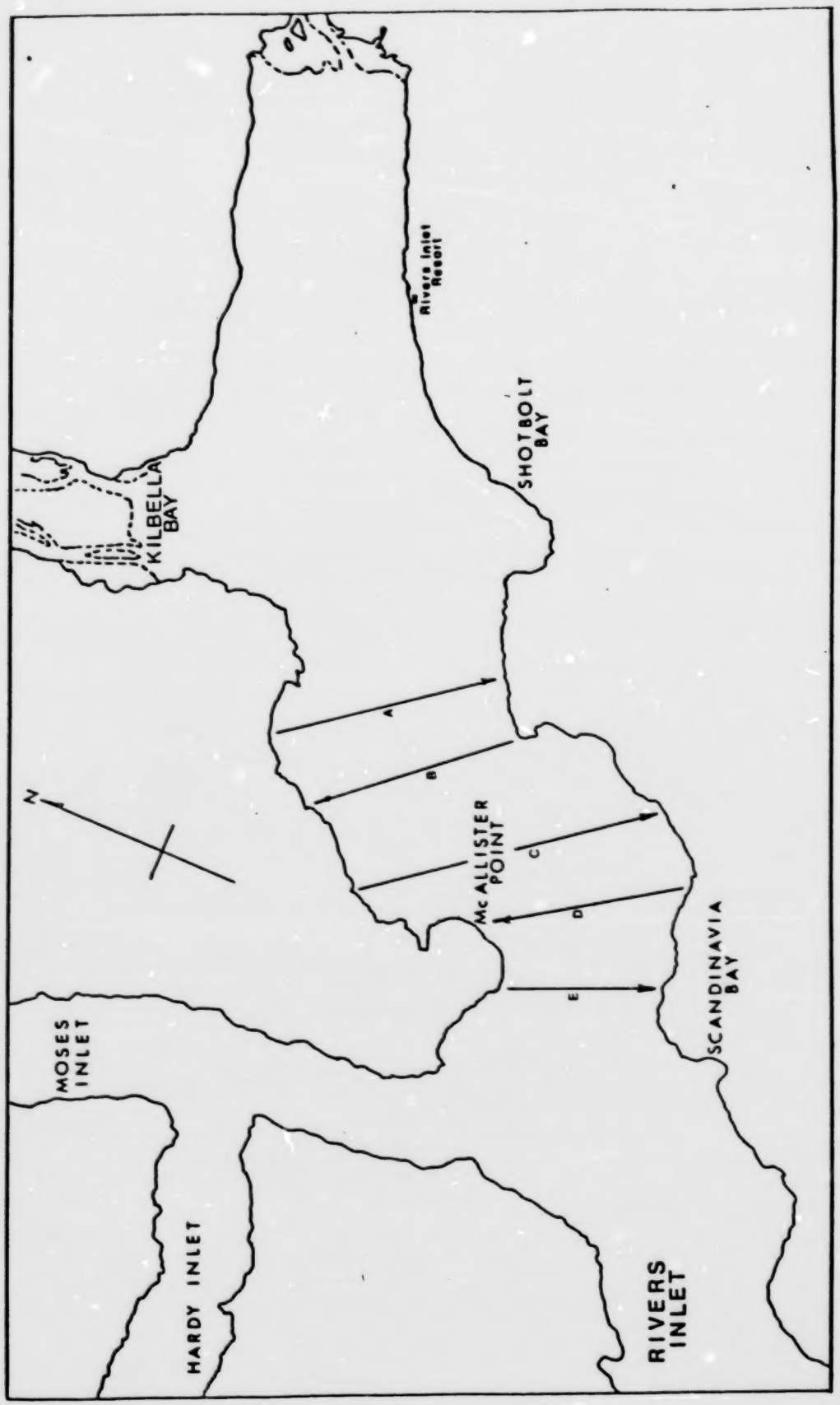

FIG. 5 R.D. 102 GRID 1971-1983

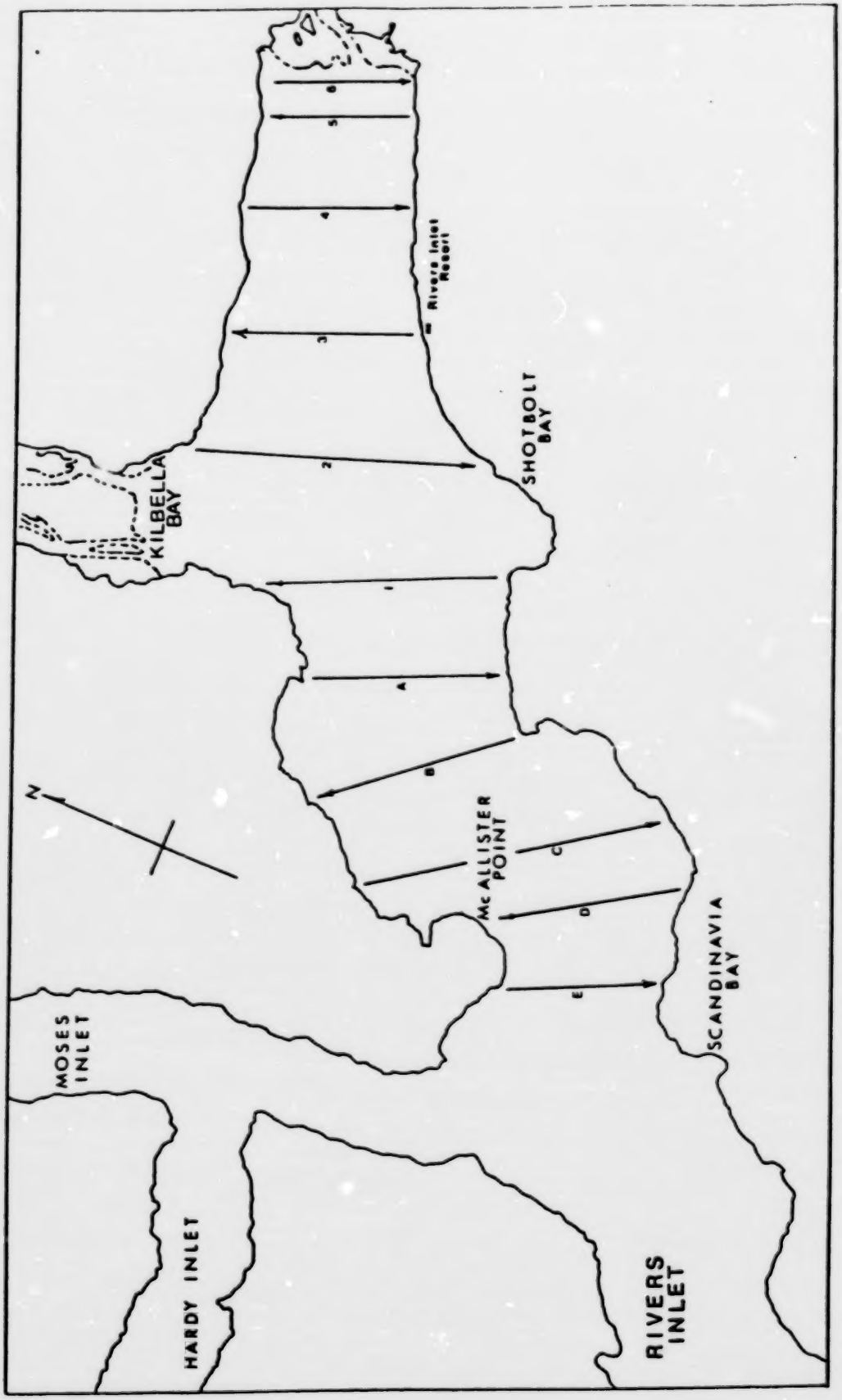

FIG. 6 MISS ROBYN AND R.D. 102 GRID 1984-1988

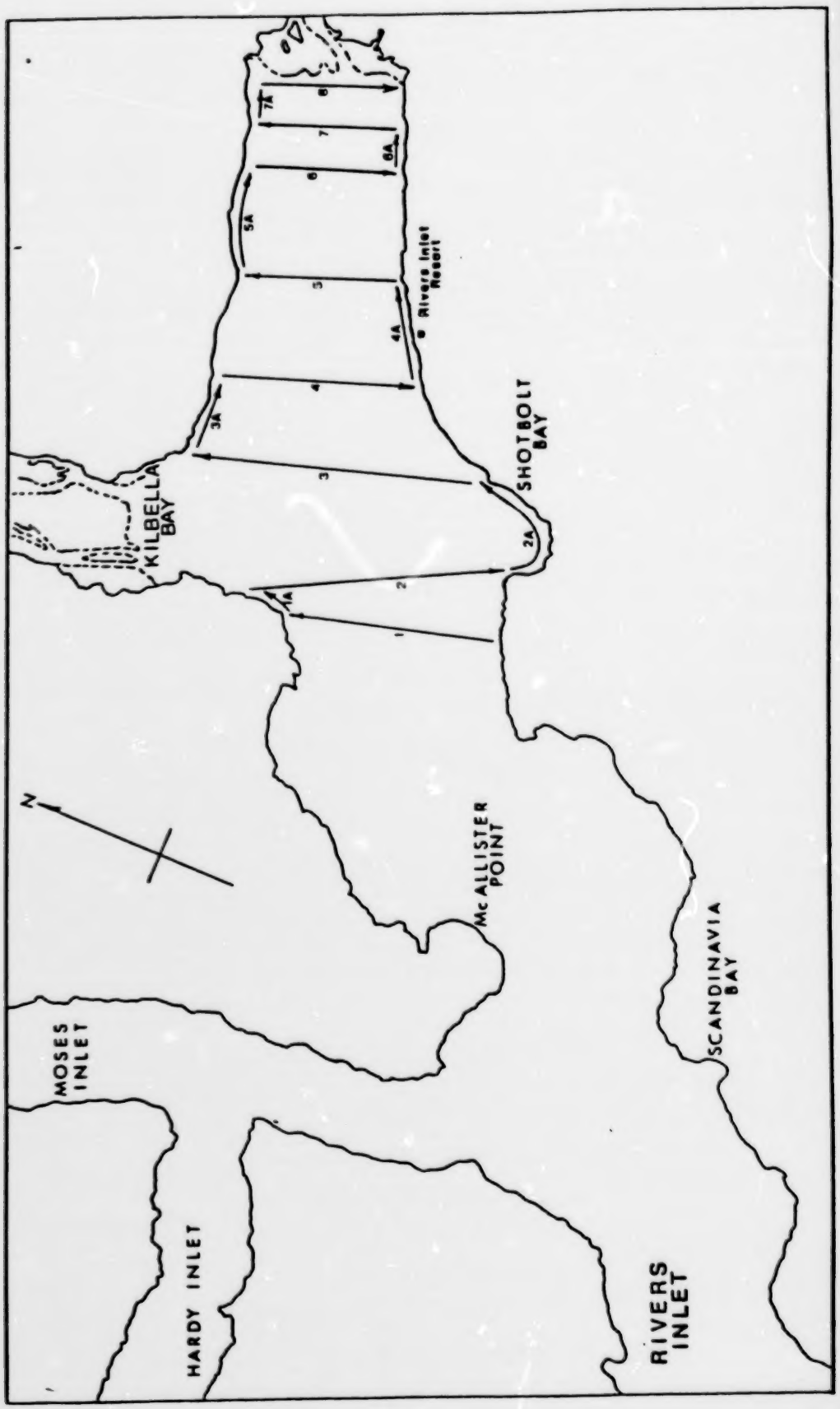

FIG. 7 THRASHER ROCK GRID 1969

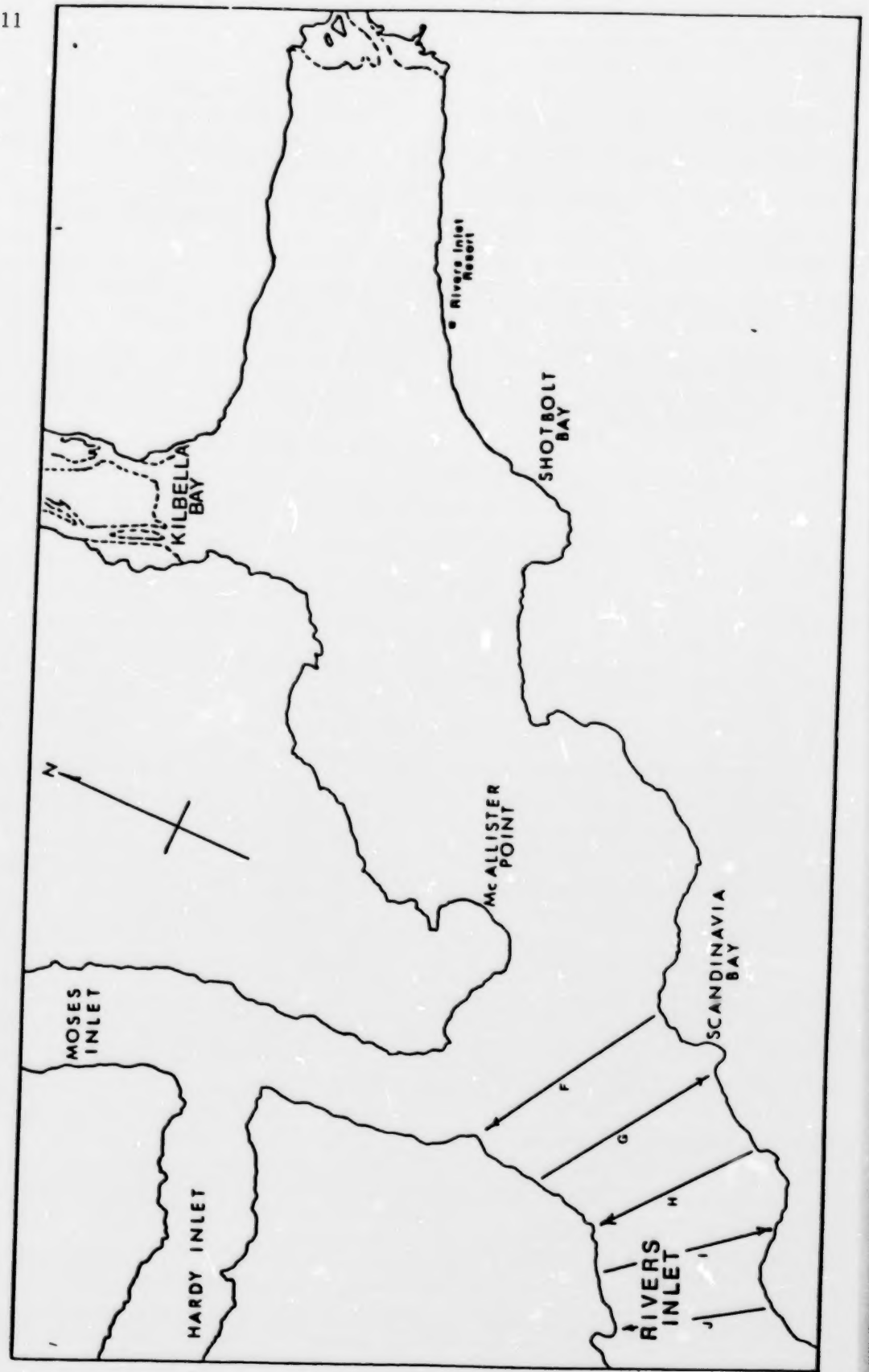

FIG. 8 THRASHER ROCK GRID 1970

FIELD METHODS

The general procedure followed during an echosounding trial is to begin at the head of Rivers Inlet, working outwards towards the mouth along the Miss Robyn and R.D. 102 grid transects. In 1984, changes were made to the transect pattern surveyed in the Miss Robyn grid area. In past years, the transects that ran across the width of the inlet were connected by shorter beach transects running parallel to the coast (Fig. 4). Within any one transect, a constant correction factor was applied to estimate the total number of fish. The use of a constant correction factor assumed that the fish density was constant along the length of the transect. However, because fish were moving through the inlet from its mouth to head, the assumption that fish density was constant along a horizontal stretch of coast was invalid. Thus, it was decided to abandon the beach transects that ran parallel to the coastline. In addition, Transect #1 of the Miss Robyn grid and Transect A of the R.D. 102 grid were adjusted to distribute survey effort evenly throughout the inlet (Fig. 6).

During the sounding, the start and end of each transect is identified on the echogram in order to allocate the fish targets to each transect. Once sounding has been completed the echogram is divided into depth strata. Echoes are recorded as inverted 'V' shaped traces. Traces recorded on the echogram are characteristic of any object having similar acoustic reflective strength as adult sockeye.

Prior to 1981, maximum and minimum visual counts of individual fish targets were determined for each depth strata. A maximum count included all targets while a minimum count only included targets that were most likely sockeye salmon. The maximum and minimum estimates for each transect were totalled to give two estimates of abundance in the grid area. A mean was then taken to give a final single count for the total area.

Since 1981, the counting of maximum and minimum targets has been discontinued. Now, only targets definitely representing salmon are counted. Appropriate depth correction factors are then applied to each of these counts. All counts are totalled to produce a surface density for the area of the transect sounded by the vessel. It is assumed that this represents the fish density throughout the transect area. The final step is to apply an area correction factor to the transect, producing an estimate of sockeye abundance for that particular transect area. The transects are totalled to give an estimate of the abundance for the total area.

ECHO COUNTING PROCEDURES

The procedure currently used to convert the recorded fish traces on the echogram into a reliable estimate of sockeye in the grid area has evolved through a series of stages. To estimate the stock size in the studied area, the area covered by the echograms is corrected to represent (Kieser and Mulligan 1984, Wood and Mason 1971):

1) a rectangle of water extending from the surface to the maximum sounded depth (depth correction), and
2) the total area of the studied site (area correction).

From 1968 to 1970, the depth was corrected to the 5-10 fathoms depth strata (Wood and Mason 1971). Then, from 1971-1983, depths were corrected to the 20-25 fathoms depth strata. In 1972, analysis of the sounding tapes indicated an overestimation of the sockeye abundance when compared to visual observations from the fall spawning ground inspections. The high correction factor applied to counts in the shallow depth zone appeared to be the cause of the overestimation. The 0-5 fathoms depth correction factor was reduced appropriately, resulting in a population estimate from the echogram that closely approximated the population estimate from visual counts on the spawning grounds.

In 1975, the uppermost depth strata surveyed was changed from 0-5 fathoms to 2-5 fathoms. This change helped to reduce counting errors caused by the freshwater interface obscuring fish targets. It was assumed that only a negligible number of fish were located in the depths between 0-2 fathoms as the fish tend to stay below the fresh-salt water interface found in this zone (Wood and Mason 1971). The altered depth range also took into account that the transducer cone forms some distance from the sounding source which is located below the draught of the sounding vessel at 1-2 fathoms depth.

Generally, over the years that the echo sounding program has been conducted, more than 95 % of the counts have been within the top 10 fathoms. On the basis of this fact, in 1984 it was decided to limit the observations to the 0-10 fathoms depth. As before, the actual calculations were performed for the depths 2-10 fathoms as the transducer cone was not formed above 2 fathoms in depth. Depth and area correction factors used in 1984 to estimate the sockeye abundance in the holding area of Rivers Inlet were developed by Kieser and Mulligan (1984). These procedures were modified in 1985 to include a volume to surface density transformation (Kieser and Mulligan 1984). In 1986 a new sounder and transducer were installed on the sounding vessel (see Appendix I). Since then, calculations have been performed on counts at 1-10 fathoms depth.

Daily sockeye abundance estimates based on the echo sounding surveys are presented in Appendix II for the years 1967-1988.

CALCULATION PROCEDURES

Over the length of the echo sounding program, the estimation procedures have been modified. Following is a description of the procedures used at different time periods.

1967, 1971-1983 Estimation Procedures

Derivation of the depth correction factors relied on the assumption that the pulse produced by the transducer forms a cone with the width increasing proportionately with depth. The cone was then divided into depth strata of 5 fathoms each (Fig. 9). Correction factors were applied to the echo counts recorded at each depth to standardize the area of water surveyed to represent a rectangle with dimensions equal to the mid-depth by the mid-width of the maximum depth strata.

The full beam angle of the cone was determined by lowering objects at various known distances from the transducer until they appeared on the echogram. Through trigonometric means the full beam angle was calculated to be 42 degrees.

The initial step to determine the depth correction factors was to calculate the proportion each depth strata was of the total corrected area. The area of each depth strata was calculated from the strata width at mid-depth and strata thickness. Cone width at the mid-depth of each depth strata (distances A, B, C, D and E, Fig. 10) was calculated by:

Cone Width at given depth = Beam angle (degrees) * # degrees/radian * depth (ft) (or fathoms)

EXAMPLE Cone width 15 ft (or 2.5 fathoms)
= 42° * .0175 * 15 ft (2.5 fathoms).
=11.025 ft or 1.875 fathoms.

Cone Width of Each Depth Strata (Beam angle = 42°)

Mid-depth	Depth (feet)	(fath.)	Cone Width (feet)	(fath.)
A	15	2.5	11.025	1.84
B	45	7.5	33.075	5.51
C	75	12.5	55.125	9.19
D	105	17.5	77.175	12.86
E	135	22.5	99.225	16.54

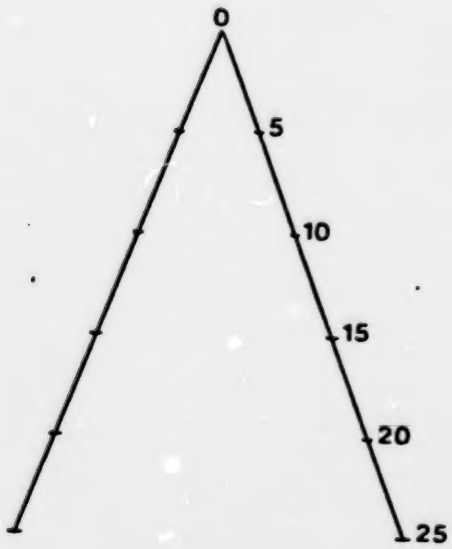

FIG. 9 TRANSDUCER BEAM DIVIDED INTO 5 FATHOM DEPTH STRATA

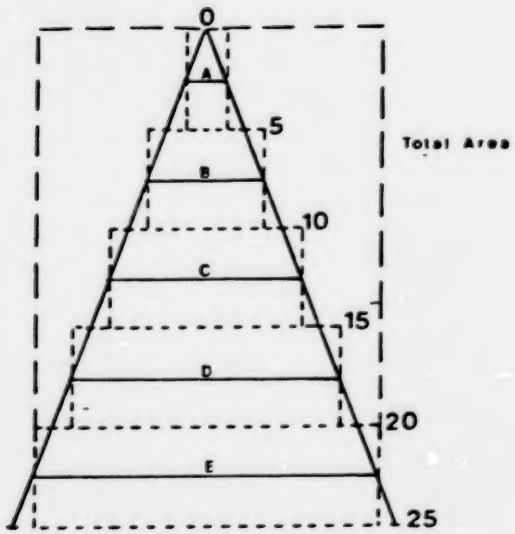

FIG. 10 MID-DEPTH WIDTHS AND AREAS OF DEPTH STRATA

The area associated with each strata can then be calculated by:

$$A = W * D$$

EXAMPLE Area (15 ft.)= Cone width (15 ft.) * Height of Strata
= 11.025 ft. * 30 ft.
= 330.75 sq. ft.

Area of Each Depth Strata (Beam Angle = 42°)

Depth Strata (fath.)	(feet)	Area (sq. ft)	(sq. fath.)
0-5	0-30	331	9.2
5-10	30-60	992	27.6
10-15	60-90	1654	46.0
15-20	90-120	2315	64.3
20-25	120-150	2977	82.7

The depth correction factors are the ratios of the area of the 20-25 fathom depth zone to the area of each depth strata.

Depth Correction Factor = Area of maximum depth/ Area of selected depth

EXAMPLE Depth Correction Factor (0-5 fath.)

Area of Largest Depth Zone/Area of Mid-depth Zone (0-5 fath).
= 2976.75 sq ft. / 330.75 sq. ft.
= 9.00

1967-1983 Depth Correction Factors[1]

Depth Strata (fath.)	(feet)	1967	1971-72	1972-74	1975-83
0-5	0-30	9.00	9.00	5.25	6.40
5-10	30-60	3.00	3.00	3.00	3.00
10-15	60-90	1.80	1.80	1.80	1.80
15-20	90-120	1.28	1.29	1.29	1.29
20-25	120-150	1.00	1.00	1.00	1.00

[1]1968-1970 Depth correction factors were significantly changed. Consult Wood and Mason 1971 for details.

These factors were applied to the fish echo counts recorded for each depth strata to determine the fish density at each depth strata. The fish densities for each strata were then summed to give a total surface density for the rectangular area defined as being the sounded transect length by the maximum strata width.

Calculation of Area Correction factors:

The surface area sounded by the sounding vessel was the transect length by the width of the deepest strata. The area correction factors were the ratios of the total transect area to the area sounded within the transect. The area correction factors were applied to the calculated surface densities of the sounded transect areas to determine the total surface densities for each transect area. Transect areas and lengths were taken from the report by Wood and Mason 1971.

1967-1983 Area Correction Factors[1]

	Transect	1967,1971-83
Miss Robyn Grid	1	28.61
	1A	16.89
	SB	20.88
	2	49.24
	2A	19.35
	3	48.03
	3A	17.64
	4	38.84
	4A	15.32
	5	24.88
	6	16.49
R.D. 102 Grid	A	23.89
	B	25.48
	C	32.92
	D	32.92
	E	42.47
Thrasher Grid	F	30.30
	G	26.32
	H	21.74
	I	21.74
	J	27.03

[1]Area correction factors used in 1968-1970 changed significantly, consult Wood and Mason 1971.

EXAMPLE Calculations for 1971 Transect #1

Depth Strata (fath.)	(feet)	Depth Correction Factor	Echo Count In Depth Strata	Corrected Echo Count In Each Depth Strata
0-5	0-30	9.00	10	90.00
5-10	30-60	3.00	8	24.00
10-15	60-90	1.80	3	5.40
15-20	90-120	1.28	2	2.56
20-25	120-150	1.00	2	2.00
			TOTAL	123.96 fish

Transect #1 Length = 1.45 nautical miles = 8819.9 ft.
Area sounded by vessel = Length of transect * mid-depth width of deepest strata

= 8819.9 ft. * 99.225 ft.
(1469.98 fath. * 16.54 fath.)

= 875055.35 sq. ft.
(24313.5 sq. fath.)

Area Correction factor(1) = Transect area(1)/Sounded area(1)
= 25,220,137 sq. ft./875055.35 sq. ft.
= 28.8

Total Number of Fish in Transect #1 = surface density(1) * area correction factor a(1)
= 123.96 fish * 28.8
= 3570 fish

Slight differences between the above calculated correction factors and the original factors are the result of round off errors.

1984 Estimation Procedure

Explanation of characters used in calculations:

v = vessel velocity (m/sec)
n = p*t number of pings for this transect (#)
p = ping rate (#/sec)
t = time to run transect (sec)
d = distance along transect (m)
L = d/n distance between pings (m)
θ = 0.5 * beam angle (degrees)
R = (4L)/((2pi)(sin θ)) depth range
r(i) = s(i+1) - s(i) thickness of i^{th} depth strata
s(i) = depth of i^{th} strata
C(i) = echo count in i^{th} depth strata
D(i) = depth correction factor for i^{th} depth strata
a(j) = area correction factor for j^{th} transect

e(i) = effective insonified volume for one ping (m^3)

1) cone volume = $pi/3\sin^2\theta * (s(i+1)^3)$
if $L/2R\sin\theta >= pi/4$

2) wedge volume = $L\sin\theta(s(i+1)^2 - s(i)^2)$
if $L/2R\sin\theta < pi/4$

For 1984, the depth and area correction factors used to estimate sockeye abundance in the holding area of Rivers Inlet were developed by Kieser and Mulligan (1984).

Step 1 Calculation of Depth Range R

The effective volume of water insonified by the transducer is approximated by a volume equation for either a cone or wedge. Initially, it needs to be determined which equation is appropriate for use in subsequent calculations. The decision is based on the value of the depth range (R) which is a function of the distance between pings and the angle of the transducer beam.

if R =< 1.459 m then the cone effective volume equation is used

if R > 1.459 m then the wedge effective volume equation is used

Calculation of Depth Range (R):

EXAMPLE J.R.C. Sounder on the WALKER ROCK
cone angle- 40° (angle θ = 20°)
boat speed- 2.65 m/sec at 800 r.p.m.
ping rate- 3.33/sec for a J.R.C. at 0-60 meter depth setting

$R = 4L/((2pi)(\sin\theta))$
where $L = d/n$
d (distance along transect) = vessel velocity (v) * time (t)
n (number of pings for transect) = ping rate (p) * time (t)

therefore:

$L = v*t/p*t$
$= v/p$
$= 2.65$ m/sec / 3.33/sec
$= .796$ m

thus:

$R = (4)*(.796) / ((2pi)*(\sin 20°))$
$= 1.48$

Therefore, the wedge effective volume equation will be used in the following examples.

Step 2 Calculation of Wedge Effective Volume

The wedge effective volume for a beam angle of 40° (θ = 20°) is:

$$e(i) = L\sin 20° \ (s(i+1)^2 - s(i)^2)$$

Depth correction factors are then calculated as a function of the strata thickness (r) and insonified volume (e):

$$D(i) = r(i)/e(i)$$

EXAMPLE Calculation of depth correction factors

Strata Depth	Depth of Strata fathoms	metres
s(1)	2	3.66
s(2)	3	5.49
s(3)	6	10.97
s(4)	9	16.46

Thickness of Strata

Strata Thickness	Depth	fathoms	metres
r(1)	2-3 fathoms	1	1.83
r(2)	3-6 fathoms	3	5.49
r(3)	6-9 fathoms	3	5.49

$e(1) = L\sin\theta\ (s(2)^2 - s(1)^2)$
$= (.796)_3 \sin 20^\circ\ (5.49^2 - 3.66^2)$
$= 4.56\ m^3$

$D(1) = r(1)/e(1)$
$= 1.83/4_2 56$
$= .401/m^2$

Effective Volumes and Depth Corrections by Strata

r(i)	e(i)	D(i)
r(1)	$4.56\ m^3_3$	$.401/m^2_2$
r(2)	$24.56\ m^3$	$.224/m^2$
r(3)	$41.00\ m^3$	$.134/m^2$

EXAMPLE Area Correction Factor (Miss Robyn Grid, Transect #6):

Area Correction Factor = Transect area / # pings in transect
$a(6) = A/n$
since $L = d/n$
$n = d/L$
Transect length (d) = 2000 m
Area of transect #6 = 677,000 m^2
therefore:
$a(6) = 677{,}000/(2000/.796)$
$= 269\ m^2$

1984 Area Correction Factors by Transect (L = .796)

Transect		Correction Factor
Miss Robyn Grid	1	1318
	2	1299
	3	1313
	4	1010
	5	630
	6	269
R.D. 102 Grid	A	1016
	B	1229
	C	817
	D	781
	E	643

The estimated number of fish per transect is then calculated by:

Total Count for j^{th} Transect =
([sum of each Echo Count C(i) * depth correction factor D(i)]
* area correction factor for the transect)

or

or $N(j) = (C(1)D(1) + C(2)D(2) + ...) * a(j)$

1985-1988 Estimation Procedure

The following procedure was begun in 1985 to estimate the sockeye abundance in the holding area. It follows a similar format as the preceding method, however it incorporates a volume density to surface density transformation designed to improve the final estimate of the number of fish (Kieser and Mulligan 1984).

Additional characters used in calculations

$V(i) = C(i)/n*e(i)$ volume density ($\#/m^3$)
$S(i) = r(i)V(i)$ surface density ($\#/m^2$)

$S^{TOT} = S(i) + S(i+1) + ...$ total surface density ($\#/m^2$)
A = area for transect m^2
$N = A * S^{TOT}$ total number of fish in transect (#)

EXAMPLE R.D. 102 Grid, Transect B

distance along transect (d) = 2800 m
area of transect (A) = 4,322,000 m^2
number of pings along transect (n) = 3500
(n can also be derived from p*t)

Step 1

The initial step is to decide which equation for effective volume should be used, where:

if R =< 1.459 the equation for the cone effective volume is used

if R > 1.459 the equation for the wedge effective volume is used

Calculation of Depth Range (R):

$R = 4L/((2\pi)(\sin\theta))$ where $L = d/n$
$= 2800/3500$
$= .800$

$\theta = 20°$

$R = (4)\ (.800)/((2\pi)(\sin 20°))$
$= 1.49$

Therefore the wedge effective volume equation will be used.

Step 2

$$e(i) = L\sin\theta\ (s(i+1)^2 - s(i)^2)$$

where:

Thickness of Strata

Strata Thickness	Depth	fathoms	metres
r(1)	2-3 fathoms	1	1.83
r(2)	3-5 fathoms	2	3.66
r(3)	5-7 fathoms	2	3.66
r(4)	7-10 fathoms	3	5.49

Depth of Strata

Strata Depth	fathoms	metres
s(1)	2	3.66
s(2)	3	5.49
s(3)	5	9.14
s(4)	7	12.8
s(5)	10	18.29

Effective Insonified Volume

$$e(i) = L\sin\theta(s(i+1)^2 - s(i)^2)$$

Strata Thickness	e(i)
r(1)	$4.58m^3$
r(2)	$14.61m^3$
r(3)	$21.97m^3$
r(4)	$46.70m^3$

The density of fish per volume of water is calculated as:

$$V(i) = C(i)/(n*e(i))$$

The density of fish per volume is then transformed into a density of fish per surface area:

$$S(i) = r(i)*V(i)$$

Volume Density and Surface Density for Counts C(i)

e(i)	C(i)	V(i)	S(i)
e(1)	5	$3.12*10^{-4}/m^3$	$5.71*10^{-4}/m^2$
e(2)	35	$6.84*10^{-4}/m^3$	$2.50*10^{-3}/m^2$
e(3)	63	$8.19*10^{-4}/m^3$	$3.00*10^{-4}/m^2$
e(4)	21	$1.28*10^{-4}/m^3$	$7.03*10^{-4}/m^2$

The total surface density is the sum of the surface densities for each depth strata.

$$S^{TOT} = S(1) + S(2) + S(3) + S(4)$$
$$= .0068/m^2$$

The total estimated number of fish in the transect is thus the density of fish in the surface area times the transect area.

$$N = A * S^{TOT}$$
$$= 4,322,000\ m^2 * .0068/m^2$$
$$= 29,277 \text{ fish in transect}$$

REFERENCES

Forbes, S.T. and O. Nakken (eds). 1972. Manual of methods for fisheries resource survey and appraisal. Part 2. The use of acoustic instruments for fish detection and abundance estimation. FAO Manuals in Fisheries Science No. 5.

Kieser R . and T.J. Mulligan. 1984. Analysis of echo counting data: a model. Can. J. Fish. Aquat. Sci. 41:451-458.

Thorne, Richard E. 1983. Hydroacoustics. In Larry A. Nielson and David L. Johnson (eds). Fisheries techniques. American Fisheries Society. p. 239-259.

Wood, F .E.A. and B. Mason. 1971. Echo sounder enumeration of Rivers Inlet Sockeye Salmon, 1967-1970. Technical Report 1971-12, Canadian Dept. Fisheries and Forestry, Fisheries Service.

APPENDIX 1. ECHO SOUNDING EQUIPMENT USED FROM 1967 TO 1988

YEAR	VESSEL	SOUNDER	FREQUENCY
1967	Cape Sea II	Furuno Model 701 "Midget"	50 kHz
1968	Cape Sea II	Furuno Model 860A	50 kHz
1969	Miss Robyn	Furuno Model 701 "Midget"	50 kHz
1970	Miss Robyn	Furuno Model 701 "Midget"	50 kHz
1971	Miss Robyn	Furuno FM 21/22	50 kHz
1972	Miss Robyn	Furuno FM 21/22	50 kHz
1973	Miss Robyn	Furuno FM 21/22	50 kHz
1974	Thrasher Rock	Furuno FM 21/22	50 kHz
1975	Thrasher Rock	Furuno FM 21/22	50 kHz
1976	R.D. 102	Furuno FM 21/22	50 kHz
1977	Walker Rock	Furuno FM 21/22	50 kHz
1978	Walker Rock	Furuno FM 21/22	50 kHz
1979	Walker Rock	Furuno FM 21/22	50 kHz
1980	Walker Rock	Furuno FM 21/22	50 kHz
1981	Walker Rock	Furuno FM 21/22	50 kHz
1982	Walker Rock	Furuno FM 21/22	50 kHz
1983	Walker Rock	J.R.C. Model JFF 111	50 kHz
1984	Walker Rock	J.R.C. Model JFF 111	50 kHz
1985	Walker Rock	J.R.C. Model JFF 111	50 kHz
1986	Walker Rock	EY-M Simrad	70 kHz
1987	Walker Rock	EY-M Simrad	70 kHz
1988	Walker Rock	EY-M Simrad	70 kHz

1967-1985 Beam Angle = 42°, 1986-1988 Beam Angle = 30°

Additional equipment:

1968: a 200 kHz (7°) transducer
1969: used an additional sounding vessel "Thrasher Rock" equipped with a Ross straight line sounder and a 106 kHz (7°) transducer. No soundings available.
1970-1973: intermittent soundings by "Thrasher Rock" using a Furuno FM 21/22 sounder with a 50 kHz (42°) transducer.
1974-1976: additional soundings by "R.D. 102".
1977-79: additional soundings by "R.D. 106".

APPENDIX II. Estimated daily sockeye abundance by year.

DATE		1967*			1968			1969			1970			1971	
		MISS ROBYN	R.D. 102	TOTAL	MISS ROBYN	R.D. 102	TOTAL	MISS ROBYN	R.D. 102	TOTAL	MISS ROBYN	R.D. 102	TOTAL	MISS ROBYN	R.D. 102	TOTAL
JUNE	28/29										407		407			
	29/30										124		124			
	30/1										1405		1405			
JULY	1/2							3603		3603	1099		1099			
	2/3							2755		2755	1965		1965			
	3/4							2646		2646	1205		1205			
	4/5							1688		1688	2691		2691	11305		11305
	5/6				15381		15381	1915		1915	2366		2366	12217		12217
	6/7				12560		12560				1125		1125	9436		9436
	7/8	126094		126094							1085		1085	5358		5358
	8/9	114287		114287				4328		4328	1538		1538	5116		5116
	9/10							3161		3161	1306		1306			
	10/11							7651		7651	1802		1802			
	11/12				41442		41442	7537		7537	2291		2291	7956		7956
	12/13				58498		58498	13204		13204	5876		5876	13709		13709
	13/14	97621		97621	61079		61079				3257		3257	11880		11880
	14/15	95861		95861	66305		66305				3989		3989	31793		31793
	15/16	96161		96161				58403		58403	4004		4004	13041		13041
	16/17							58630		58630	4251		4251			
	17/18				124212		124212	59512		59512	1357		1357	118998		118998
	18/19				107976		107976	62261		62261	1005		1005	201911		201911
	19/20				122264		122264	21504		21504	1123		1123	248797		248797
	20/21				98621		98621				8927		8927	262288		262288
	21/22	201663		201663							13394		13394			
	22/23	233442		233442				49022		49022	20847		20847	346633		346633
	23/24	160617		160617				58084		58084	21293		21293	351326		351326
	24/25							42301		42301	19916		19916	358499	30609	389108
	25/26							34003		34003	22840		22840	314107	17232	331339
	26/27							41425		41425	15858		15858	315732		315732
	27/28				80185		80185				23515		23515	358191		358191
	28/29	193199		193199	49152		49152				26068		26068	412411		412411
	29/30	107095		107095	43387		43387	22228		22228	28828		28828	333764		333764
	30/31	81185		81185	46823		46823	20587		20587	28170		28170	333949		333949
	31/1				36584		36584	7268		7268	25185		25185	157597		157597
AUG	1/2				43793		43793	5501		5501	15563		15563	67595		67595
	2/3				42545		42545				7525		7525	53976		53976
	3/4				27443		27443				5334		5334			
	4/5	43768		43768	27562		27562									
	5/6	96811		96811												
	6/7	35894		35894												

* 1967 sounding conducted during daylight hours

APPENDIX II (cont.). Estimated daily sockeye abundance by year.

		1972			1973			1974			1975			1976			1977		
		MISS	R.D.		MISS	R.D.		MISS	R.D.		MISS	R.D.		MISS	R.D.		MISS	R.D.	
DATE		ROBYN	102	TOTAL	ROBYN	102	TOTAL	ROBYN	102	TOTAL	ROBYN	102	TOTAL	ROBYN	102	TOTAL	ROBYN	102	TOTAL
JUNE	28/29																		
	29/30																		
	30/1																		
JULY	1/2				2762		2762												
	2/3				3460		3460												
	3/4	5656		5656	6715		6715												
	4/5	17272		17272	1924		1924												
	5/6	14811		14811	13419		13419												
	6/7	21153		21153	10629		10629												
	7/8	23142		23142	3238		3238												
	8/9				2990		2990												
	9/10				8472		8472												
	10/11	59209		59209	21965		21965										15278		35278
	11/12	98596		98596	23981		23981											18445	18445
	12/13	153600		153600		73200	73200												
	13/14	118478		118478	18537		18537	3634		3634									
	14/15	105138		105138	139211		139211	2677		2677							60482		60482
	15/16	121203		121203				3427		3427		5689	5689					37875	37875
	16/17	143964		143964				16141	24620	40761									
	17/18	182539		182539	359475	101339	460814	49057	8909	57966		32315	32315				140294	51386	191680
	18/19	238523		238523	509923	35112	545035	59610	7491	67101	853	23111	23964	166481		166481	167247	57245	224492
	19/20	218058		218058		304618	304618	94467		94467		17706	17706	143070	139112	282182	204182	28213	232395
	20/21	229917		229917		233685	233685	110220		110220							180760		180760
	21/22	244797		244797	464815		464815	120500	17136	137636	48498	19442	67940	291208		291208		76608	76608
	22/23	226016		226016				126960	27705	154665	57979		57979				236672	25862	262534
	23/24	267679		267679				135146	34187	169333	48235	58446	106681				220882		220882
	24/25	212893		212893							81657		81657	270541		270541	254821		254821
	25/26	321799		321799							109867	67011	176878				211217	12907	224124
	26/27	299230		299230							86088		86088						
	27/28	273795		273795							52822	27113	79935	283760		283760			
	28/29	261724		261724							74478		74478	287954		287954			
	29/30										49541		49541						
	30/31	205400		205400															
	31/1	174583		174583							50474		50474						
AUG	1/2	117911		117911							34559		34559	248502		248502	59685		
	2/3																		
	3/4																		
	4/5																		
	5/6																		
	6/7																		

APPENDIX II (cont.). Estimated daily sockeye abundance by year.

DATE	1978 MISS ROBYN	1978 R.D. 102	1978 TOTAL	1979 MISS ROBYN	1979 R.D. 102	1979 TOTAL	1980 MISS ROBYN	1980 R.D. 102	1980 TOTAL	1981 MISS ROBYN	1981 R.D. 102	1981 TOTAL	1982 MISS ROBYN	1982 R.D. 102	1982 TOTAL
JUNE 28/29															
29/30							693	2951	3644						
30/1															
JULY 1/2							1748	3138	4886						
2/3															
3/4								2110	2110						
4/5															
5/6															
6/7															
7/8															
8/9	37502		37502				10266	12399	22665						
9/10	38819		38819												
10/11	35060		35060	16150		16150	7106	42508	49614						
11/12	38621		38621	11853	20131	31984							7333	45338	52671
12/13	85976		85976	20001		20001	139532	38390	177922	89798		89798	10158	49103	59261
13/14				18015		18015	174680	59730	234410		182512	182512		48112	48112
14/15	90371		90371	30227	23377	53604	152221	82148	234369	54174	115688	169862	13575	50441	64016
15/16	63052		63052				160847	108513	269360	120135		120135		131286	131286
16/17	73782		73782	40723	50223	90946	207716	72453	280169		143812	143812		123245	123245
17/18	86240		86240	87020		87020	202088	82660	284748	191571		191571		95059	95059
18/19				109179		109179	207835	82544	290379	261467	145687	407154	30780	116453	147233
19/20	114890	17269	132159	161870		161870				304571		304571	29220	145207	174427
20/21	136295	17540	153835	196927		196927	207527	88284	295811	393969	176054	570023	75123	229760	304883
21/22	120641		120641	210317		210317				406794	101303	508097	129000	189856	318856
22/23	166115		166115	217650	107845	325495	96556	66277	162833	427260	202959	630219	123362	152755	276117
23/24				235744		235744				474338	254607	728945	174700	106362	281062
24/25	120854		120854	171089	57293	228382				561430	178012	739442	204516	71813	276329
25/26	91776		91776							682160	94666	776826	160621	63128	223749
26/27										593311	28499	621810			
27/28	61018		61018							562227	20770	582997			
28/29															
29/30										369885		369885			
30/31															
31/1															
AUG 1/2															
2/3															
3/4															
4/5															
5/6															
6/7															

APPENDIX II (cont.). Estimated daily sockeye abundance by year.

DATE	1983 MISS ROBYN	1983 R.D. 102	1983 TOTAL	1984 MISS ROBYN	1984 R.D. 102	1984 TOTAL	1985 MISS ROBYN	1985 R.D. 102	1985 TOTAL	1986 MISS ROBYN	1986 R.D. 102	1986 TOTAL	1987 MISS ROBYN	1987 R.D. 102	1987 TOTAL	1988 MISS ROBYN	1988 R.D. 102	1988 TOTAL
JUNE 28/29																5401	6742	12143
29/30													*	0	*	58261	9909	68170
30/1													2314	1086	3400	19854	28408	48262
JULY 1/2					20708	20708					22278	22278	*	899	899*	784	9408	10192
2/3		9967	9967	15000	62808	77808				26438	22068	48506	978*	1061	2039*	206	2813	3019
3/4		36334	36334	25770	196490	222260				63206	27064	90270	2587	3976	6563	1355	3065	4420
4/5	80617	30851	111468	13214	126182	139396				47105	29349	76454	2331	18545	20876	453	16374	16827
5/6	45812	43129	88941	47824	119774	167598				43811	25945	69756	18086	24009	42095	1399	252377	253776
6/7	23049	72903	95952	174688	58777	233465	10129	9459	19588	65858	53582	119440	47505	24642	72147	2273	157270	159543
7/8	23291	104450	127741	259860	39553	299413	36617	10678	47295	99367	147907	247274	32129	48382	80511	0	62589	62589
8/9	59709	128739	188448	341461	52492	393953	55818		55818	43269	105201	148470	9837	49368	59205	158	24853	25011
9/10	111849	76285	188134	299198	105830	405028	99293	24002	123295	53228	117315	170543	3165	47707	50872	0	7613	7613
10/11	147560	64061	211621	286400	97806	384206	134154	16396	150550	60637	191970	252607	7758	32326	40084	0	52196	52196
11/12	172442	95798	268240	384670	99535	484205				79698	102012	181710	39901	37688	77589	15971	267625	283596
12/13	218935	76010	294945	356323	28761	385084	74896	15257	90153	119590	141590	261180	88976	68861	157837	137163	518922	656085
13/14	252687	178674	431361	339467	22089	361556	96430	22363	118793	114155	101035	215190	188161	164182	352343	124205	824647	948852
14/15	237990		237990	315730	30926	346656	110875	22257	133132	88890	149583	238473	108555	139053	247608	155241	625064	780305
15/16	228469		228469	308928	34052	342980	97208	19630	116918	176436	122662	299098	188742	152515	341257	20953	412971	433924
16/17	201351	36280	237631	465011			78636	10747	89383	180361	90311	270672	234372	109358	343730	3389	480408	483797
17/18				373492			71918	12508	84426	278943	39758	318701	75796	97335	173131	321361	631529	952890
18/19													50754	98536	149290	704908	208646	913554
19/20																963007		963007
20/21																		
21/22																		
22/23																		
23/24																		
24/25																		
25/26																		
26/27																		
27/28																		
28/29																		
29/30																		
30/31																		
31/1																		
AUG 1/2																		
2/3																		
3/4																		
4/5																		
5/6																		
6/7																		

*Miss Robyn grid not completely sounded

APPENDIX III. Estimated daily abundance in Thrasher Rock Grid by year.

DATE	1970	1971	1972	1973	1974	1975	1977
JUNE 29/30	1198						
30/1	1316						
JULY 1/2	4854						
2/3	3951						
3/4	6174						
4/5	7553						
5/6	4939						
6/7	3934						
7/8	4914						
8/9	4009						
9/10		9042					
10/11		5749	59793		3171		
11/12	4176		9818				
12/13	2769		7845	83972			
13/14	4757		12958				
14/15	3571		21508				
15/16			39288			9372	14482
16/17		8889	35383				
17/18			35114			48817	
18/19	19203		40966				
19/20	14910		84506			31422	
20/21	9595		14299				
21/22	10898		37340				18177
22/23	12023	20183	31407				
23/24	15074		29947				
24/25	10793		70945				
25/26	12239		67482				
26/27	14344						
27/28	8689						
28/29							
29/30	12360	237159					
30/31	10246						

APPENDIX IV. Transect lengths and areas for the Miss Robyn and R.D. 102 Grids, 1984-1988.

Transect		Length (m)	Area (m^2)
Miss Robyn Grid	1	3,330	5,514,000
	2	3,480	5,681,000
	3	2,370	3,909,000
	4	2,170	2,754,000
	5	1,910	1,512,000
	6	2,000	677,000
R.D. 102 Grid	A	2,540	3,243,000
	B	2,800	4,322,000
	C	4,040	4,148,000
	D	2,590	2,541,000
	E	2,220	1,793,000